Alabama Research and Development Enhancement Fund
Quarterly Report
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Background

The Alabama Innovation Act (AIA) was established by Legislative Act #2019-404 and became effective June 6, 2019. The Act designated the Alabama Department of Economic and Community Affairs (ADECA) as the state agency to establish and administer the Alabama Research and Development Enhancement Fund (ARDEF) Program.

The purpose of the ARDEF Program is to encourage new and continuing efforts to conduct research and development activities within the state. The Fund is designated to receive appropriations from the legislature, or from the receipt of gifts, grants, or federal funds to be expended for the purpose of increasing employment opportunities and products and services available to the citizens of Alabama.

Overview of 2020 Program Year

Projects Funded Under 2020 Round One Grant Period

Applicant	Amount
Auburn University – Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Water and Landfill Leachate in Alabama	$193,960.00
Auburn University – Knitting Micro-Resolution Mosquito Bite Blocking Textiles	$868,145.00
Auburn University – Advanced Biosensors from Forestry Products and Agricultural Resources	$245,864.77
HudsonAlpha Institute for Biotechnology – Advancing Genomic Health in Community Clinics and Employee Wellness Settings	$969,409.00

Auburn University – Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Water and Landfill Leachate in Alabama

This project aimed to remove and destroy the so-called forever chemicals, per- and polyfluoroalkyl substances (PFAS), from Alabama water and landfill leachate. PFAS have been detected in chemical manufacturing wastes and landfill leachate in Alabama and have caused some serious cases of drinking water contamination in the state. Ongoing health concerns and regulatory development associated with PFAS are threatening the sustainable development of the Alabama economy and business. The goal of this research was to develop an innovative "Concentrate-&-Destroy" technology to cost-effectively remove and degrade PFAS in water and landfill leachate. The new remediation technology will provide the affected industries and water utilities with a powerful remediation means to mitigate the PFAS-related issues, thereby assuring sustainable development of the economy and the wellbeing of Alabama citizens.

Within this quarter, our research focused on evaluating the effectiveness of Ga/TNTs@AC for treating PFOS spiked in Alabama field water. We found that a fixed-bed column packed with Ga/TNTs@AC was able to effectively remove PFOS from 100 µg/L to <1 µg/L for 2281 bed volumes under the field water matrix conditions. Upon saturation, the PFOS removal capacity was estimated to be 165.5 µg/g.

Based on our preliminary screening data, Bi/TNTs@AC offered the highest defluorination activity among three model materials tested, with a defluorination of 47%.

Auburn University – Knitting Micro-Resolution Mosquito Bite Blocking Textiles

Insects transmit crippling diseases to humans. Nearly a half-million people die of malaria each year. In Alabama, citizens encounter Dengue and Zika virus invasions as well as a multitude of encephalitis variants. The worse vector-borne diseases are transmitted in the hottest climates like Alabama, and it is uncomfortable to wear the thickest clothing. This project will research different textile and weave patterns to create clothing that is cool in heat and capable of blocking mosquito bites and develop prototypes based on this research. Beyond the prototype phase, research will be done to measure the effectiveness this product will have on the Alabama economy.

During this quarter we completed all testing of our initial prototypes in areas of thermal conductivity, feel tests, water retention, and air permeability. One of our blocking knits is close in comfort to other comfortable clothes like Under Armour. The next phase of our experiments are now to determine which fibers add to comfort measurements. We have re-knitted the initial prototypes with spandex yarns and are now comparing how the addition of spandex impacts comfort. We also developed a simulation software that can simulate knit geometries in collaboration with Jim McCann from Carnegie Mellon University. To build ties with industry partners, we developed an internship with Auburn knitting company Straehle + Hess to develop a market plan for manufacture and sale of the textiles. We developed a business plan and motto. Additionally, we met with patent attorneys and are in the process of converting our provisional patent into a full PCT filing. Finally, one master's student, Bryan Holt, in biosystems engineering graduated during this quarter.

Auburn University – Advanced Biosensors from Forestry Products and Agricultural Resources

The main goal of this project is to utilize Alabama's forestry products and agricultural resources for extracting cellulosic nanomaterials (CNM) by using these nanomaterials in advanced biosensing. As timber production and other agricultural products are essential for the economy in Alabama, these materials are a great resource for obtaining cellulosic nanomaterials.

Outstanding laboratory facilities along with the support from ADECA are enabling scientific knowledge contributions and revalorization of agricultural and forestry waste products as biosensors. Trees and crops contain tiny materials known as cellulose nanomaterials (CNMs). Developing new applications for CNMs could enable forestry and crop waste to provide additional economic benefits for Alabama citizens. An Auburn University research team is exploring using CNMs from cotton, soybean hulls, and wood to produce sensors for the detection of allergens and water contaminants. Thus far, the team has shown that CNMs can be used to absorb carbofuran which is a common pesticide. They have also shown that CNMs can be used to absorb beta-lactoglobulin, a milk allergen. In ongoing work, they are improving the chemistry to make sensors that cannot only absorb multiple species but also selectively detect the materials of interest (analytes). The long-term goal of this work is to have a family of portable CNM sensors that can be used by citizens to test for water contaminants and food allergens.

This project is focused on using Alabama's forestry and agricultural products such as wood, cotton, and soybean hulls as sources of an exciting nanomaterial called cellulose nanocrystals (CNC). Cellulose nanocrystals are found in all biomasses. Their high strength, large specific surface area, and natural organic chemistry make them exciting for a range of applications. We are focused on developing sensors to improve water safety and the health of Alabama citizens. Specifically, we are working on modifying CNCs to enable them to be used to detect pesticide residues in water. We are also exploring their use in detecting food allergens such as milk allergen, β-lactoglobulin. We are using laboratory tools such as Quartz Crystal Microbalance with Dissipation (QCMD) and Surface Plasmon Resonance (SPR) to validate our approach. So far, we have increased the stability of the CNC when exposed to water and demonstrated analyte absorption. Our current focus is on increasing the selectivity of the detection and understanding differences between the agricultural and forestry derived CNC's. The outstanding lab facilities of Auburn University and the support from ADECA are helping the research team continue to gain insights on how an exciting material hiding in our abundant forestry and agricultural resources can be transformed to enable Alabama citizens to detect contaminants and allergens in their water and food.

HudsonAlpha Institute for Biotechnology – Advancing Genomic Health in Community Clinics and Employee Wellness Settings

Genomic medicine is a form of precision medicine that uses approaches customized to each patient to treat disease and optimize prescription medicine based on a genetic profile. This project will test and develop a genomic health complete delivery system for Alabama patients and physicians at healthcare systems and community hospitals with limited expertise in genomics. This system includes 1) Partnering with Auburn University to develop community-based models for health programs, 2) Refining and optimizing the process including insuring access by rural and underserved areas, and 3) Developing the health IT infrastructure needed to fully integrate genetic test reporting and education into an electronic health records system. The proposed development of new products and services will result in improved health outcomes for Alabamians, opportunities for employers to increase competitiveness and reduce costs, and modernization of health care in an equitable way for Alabama communities, large and small, regardless of socioeconomic status.

This HudsonAlpha project aims to develop and optimize genetic health screening programs with partners around the state of Alabama, including employers offering genetic testing to their employees. We continue to expand genetic testing initiatives with existing partners (Auburn University, Miles College, Drake State Community College) and are launching a new initiative with Alabama A&M University. In addition to onboarding new employer partners, we recently launched an IRB-approved research study to collect outcomes data from participants through online surveys. This study will provide valuable insight into the clinical and personal utility of genetic testing in the context of employee wellness.

Projects Funded Under 2020 Round Two Grant Period

Applicant	**Amount**
University of Alabama in Huntsville – Alabama Business Resiliency and Sustainability Index and Roadmap	$746,104.00

University of Alabama in Huntsville – Rural Employment and the Need for an Alabama Irrigated Acreage Survey, Demand Estimate and Forecast	$172,073.00
University of Alabama at Birmingham – A Comprehensive Data Science Software Toolkit to Improve Alabama's Mobility Planning for Serving Businesses and Vulnerable Populations	$394,926.00
Auburn University – Design, Fabrication and Testing of Novel Medical Facemasks to Prevent COVID-19	$75,374.00
Auburn University – Formaldehyde Paper-based Device (PAD) for a Cost-efficient Detection of Formaldehyde Emissions from Wood Panels	$247,142.00
University of Alabama at Birmingham – Commercialization of Small Diameter Artificial Vascular Graft for an Animal Trial	$906,458.00
Bashan Institute of Science – Exploring the Use of Cellulose Fibers as Microcapsules for Plant Growth-promoting Bacteria (PGPB) Inoculants	$7,500.00

University of Alabama in Huntsville – Alabama Business Resiliency and Sustainability Index and Roadmap

Recent events, such as the global COVID-19 pandemic, are having detrimental impacts on companies throughout Alabama, including the products and services they provide and the citizens they employ. Other impactful events that can occur may include the sudden loss of a major customer or supplier, a natural disaster, or even a diminishing source of skilled labor. The objective of this project is to research potential impacts on businesses and organizations across several business sectors to develop and deploy a comprehensive Resiliency and Sustainability Index and Roadmap (RSIR) model. The RSIR can be further tailored to fit each business sector and individual organization. Additionally, the UAH team will directly support businesses in the customization and implementation of their RSIR along with assistance in developing the ability to execute the roadmap and plan should the need arise.

In this quarter, the *Future Ready* assessment model has been updated with more explicative and clarifying features. The process for assessing a business has been considerably revised and now finalized. A RISR Assessment - Assessor Guide and Reference Sheet has been developed for all assessors to reference prior to and during assessments. This allows assessors to have everything they need to accurately conduct an assessment and have the correct supporting research, definitions, examples, and insider notes that help make an assessment run smoothly.

Outreach strategies and materials and customer educational materials are finalized under the *Future Ready* brand. These educational materials are provided to customers before and throughout the assessment process to explain the RISR model over-view, terminology, methodology, that will help the customer come to the assessment better prepared. A variety of effective outreach channels have been utilized, including direct email, email blast, LinkedIn post, and Chamber of Commerce or EDA dissemination. Additionally, four virtual workshops were successfully completed this quarter with over 30 participants.

Businesses are being recruited as part of the full engagement schedule. 163 companies have shown varying levels of interest in the *Future Ready* program. Two Future Ready assessments have been completed and follow-on support is being defined and prioritized. A third company is being scheduled with several more in the queue to initiate engagement. The interest level is strong for

businesses learning about *Future Ready* and most businesses express a strong desire to take advantage of it. Our team is currently working to overcome the challenge is the businesses' temporary lack of workforce availability and high demand for their products/services that consumes their bandwidth.

University of Alabama in Huntsville – Rural Employment and the Need for an Alabama Irrigated Acreage Survey, Demand Estimate and Forecast

As irrigated agriculture develops in our rural communities, it is imperative Alabama has the tools and data needed to ensure water resources are available for sustainable economic development. The goals of this project are to update the existing manual center pivot irrigation survey completed by UAH for the years to include 2017 and 2019 and develop a state-specific machine-learning framework from multiple sources of remote sensing products to efficiently and semi-autonomously identify the irrigated areas in Alabama to include all irrigated land such as golf courses and other irrigation system types beyond just center pivots. This information will be used to update the report "Estimates of Future Agricultural Water Withdrawal in Alabama", produced by the Water Resources Center, Auburn University for OWR in 2017. The result will include updated estimates as well as methodologies utilizing more recent urban growth and land use change data. The results and outcomes of this project will support the Alabama Department of Economic and Community Affairs (ADECA) Office of Water Resources (OWR) to accurately analyze and forecast water use across the State.

During Q2 2022, the team continued to map the 2021 center pivots. The results thus far show that while the rate of increase declined from 2017-2019, the 2021 data show a renewed statewide increase. The 2021 data will be completed in Q3. The team continues to improve the precision of modeling outputs meanwhile improving the code accessibility for a python-based tool that supports map generation beyond the project timeline. Q3 will conclude with a final assessment of the accuracy of the ML approach compared to the 2017 and 2019 pivot mapping.

The 2040 projections were completed in Q2. In the ChocPea region, we project irrigation to increase to 47,162 acres. We see that most of the predicted irrigation is concentrated in the south with a slight band of irrigation in the north. For Pickwick-Wheeler, we project irrigation to increase to 56,546 ac. The predicted irrigation is expected in the central and northeastern part of the region. As for Perdido-Mobile Bay (projected to 14,772 ac), the additional irrigation is concentrated in the southern part of Baldwin County. The spatial distribution of the predicted irrigation is on current cultivated crops and hay/pastureland in close proximity of current irrigation.

University of Alabama at Birmingham – A Comprehensive Data Science Software Toolkit to Improve Alabama's Mobility Planning for Serving Businesses and Vulnerable Populations

This project focuses on the development of a comprehensive data science software toolkit to support transportation planning for Alabama's businesses and vulnerable populations. Research activities include: (i) use of transportation user surveys and open data source collection to build a web-based data portal for mobility analysis in Alabama; (ii) development of agent-based urban transportation simulation models, and employment of machine learning techniques for transportation forecasts; and (iii) use of the developed tools to study scenarios that address pressing mobility needs in Alabama. Examples include (1) building a COVID-19 simulator to explore how various business reopening strategies affect the population's mobility and hence the virus spread;

and (2) studying the impact of shared mobility services such as Uber/Lyft/Via, Zyp BikeShare stations and dockless electric scooters on local traffic congestion, transit use; and accessibility and mobility of vulnerable populations. The project will provide helpful recommendations to transportation policymakers about transportation initiatives that can help Alabamians, including economically and physically disadvantaged ones, to gain access to jobs and critical amenities in an equitable and efficient manner.

During the reporting period of April to June 2022, the team has successfully built a transportation simulation model for the medium-sized city of Birmingham, Alabama. This digital twin incorporates transportation modes such as public transits and ride-hailing services, in addition to private vehicles that constitute the majority of Birmingham's traffic. We used the agent based MATSim software for transportation simulation, where realistic agent plans for Uber rides were generated based on the spatiotemporal distributions of pickup and drop-off locations collected from our Uber driver survey that we reported in the previous reporting period. The distributions were fitted using spatiotemporal network kernel density estimation. With this digital twin, transportation engineers can flexibly analyze the impact of ride-hailing services under different scenarios, such as "if the number of Uber drivers doubles" which could happen in the future. Our simulation results show that 400 Uber drivers already serve the Uber passengers in Birmingham well and increasing it further to 800 leads to a lot of drivers being idle. We also explored the impact of Uber rides to the traffic of Birmingham, and the finding is that Uber rides do not cause additional congestion in Birmingham. A demo video of our simulation with buses and Uber rides can be found at https://github.com/jalal1/UberSim.

Auburn University – Design, Fabrication and Testing of Novel Medical Facemasks to Prevent COVID-19

One of the most effective ways to prevent viral spread of the Coronavirus is to use face masks and respirators. Available reusable face masks are often not as effective as single-use coverings, which are costly and environmentally irresponsible. Currently, there is limited knowledge available on the performance of fabrics used in masks. Filtration efficiencies as a function of aerosol particulate sizes in 10 nm to 10 μm range are relevant for respiratory virus transmission but lack evaluation. The purpose of this research was to develop novel face masks to fight the pandemic based on scientific and engineering principles. In this research, novel medical face masks were designed, produced, and tested to reduce the spread of COVID-19 while improving on deficiencies present in currently used textile reusable face coverings. The project incorporates additive manufacturing, computer aided design (CAD), third party testing of both Bacterial Filtration Efficiency (BFE) and differential pressure measurements, and laser-visualization tools for illuminating leakage.

This project resulted in a textile face mask design with enhanced capabilities as compared to other textile masks currently available on the market. Through the employment of various testing methods, including bacterial filtration efficiency, breathability, initial filtration efficiency, laser leakage illumination, and performance testing, various mask iterations were evaluated and improved to perform better. Different engineering methods were utilized, including textile engineering, additive manufacturing, and laser imaging, all to construct a device with the capability of reducing the spread of COVID-19 or another disease if a pandemic such as COVID-19 were to occur again.

This research project ended May 15, 2022.

Auburn University – Formaldehyde Paper-Based Device (PAD) for a Cost-Efficient Detection of Formaldehyde Emissions from Wood Panels

Formaldehyde emission can be toxic to people depending on the time of exposure coupled with formaldehyde concentration. This level of exposure is generally not high in forest products because companies that make indoor products currently measure formaldehyde through quality control techniques. Companies also use safe adhesives ("glues") by partnering with their suppliers. Nevertheless, these companies are regulated to federal standards such as the California Air Resources Board (CARB) to ensure this safety. To assist with the more expensive and laborious methods in CARB, this project endeavors to create a relatively cheap paper-based sensor that changes color based on formaldehyde exposure. Such a product can help to reinforce the safety of our forest products while maintaining the jobs of our many Alabamians.

The project entitled "Formaldehyde paper-based device (PAD) for a cost-efficient detection of formaldehyde emissions from wood panels" focuses on the development of a prototype of a paper-based device (PAD) for measuring formaldehyde concentration in air. The ultimate goal of the project is to develop an accessible, rapid, accurate analytical tool for the determination of formaldehyde in the air at concentration levels below 1 ppm.

The progress of the research work performed during the second quarter of 2021 meets the goals described in the project's timeline. The main results are listed below:

- The preliminary data for validating the sensor are shared in the full report.
- Particle boards (PB) with low formaldehyde emission levels (<0.2 ppm) have been fabricated. The PBs will be used for measuring the FA emission using different methods, including ASTM D6007-14 and electronic FA sensors. The results will be compared with the formaldehyde emission values estimated with the paper-based sensor prototype that is being developed in our laboratory.

University of Alabama at Birmingham – Commercialization of Small Diameter Artificial Vascular Graft for an Animal Trial

The goal of the project is to finalize the development of an artificial vascular graft for surgical implantation. The graft has relevance to the current COVID-19 pandemic in that numerous patients are reporting kidney infections and blood clots. UAB has been working on this project since 2007 and has reached a point where funds are needed for an animal trial. Once this graft has been validated through this process, we plan to market it to a biomedical implant company to set up a division in Alabama or to establish a spin off company for the production and distribution. This graft has the potential for an estimated $50 million in annual sales based on conservative estimates of the number of surgical interventions that could use the implant in an unmet market and lead to a number of jobs for highly skilled workers in the State of Alabama.

We have completed the first survival animal procedure and report that the 21-day study was terminated early. During the surgical insertion of the device, it was found that the graft formed a kink in it. An ultrasound showed that blood flow was still passing through the graft after suturing, however, so the animal was kept alive for observation. After two weeks the animal was sacrificed and upon extraction it was found that the graft had formed some holes and was no longer functioning properly. We are now pausing the next planned procedures to modify the graft to increase its durability and will resume the procedures.

Bashan Institute of Science – Exploring the Use of Cellulose Fibers as Microcapsules for Plant Growth-Promoting Bacteria (PGPB) Inoculants

Inoculation of plants with plant growth-promoting bacteria (PGPB) that enhance the yield of crops and growth performance of environmental plants is an old practice. Two main factors control the success of inoculation—effectiveness of the bacteria and application technology. If the suspensions of bacteria are inoculated into the soil without a proper carrier, the bacteria population declines rapidly. These unprotected inoculated bacteria must compete with the often better-adapted native microflora and withstand predation by soil microfauna. Consequently, a major role of formulation of bioinoculants is to provide a more suitable microenvironment, combined with physical protection for a prolonged period to prevent a rapid decline of introduced bacteria. This project explored the feasibility of using cellulose fibers as carriers, to improve survival and enhance the PGPB viability.

This research project ended March 15, 2022.

Overview of 2022 Program Year

Projects Funded Under 2022 Grant Period

Applicant	Amount
The University of Alabama – Innovative Wood-Concrete Composite Structural Elements for Resilient Modular Building and Transportation Structures	$341,679.00
Auburn University – Advanced Liquid Transportation Fuels from Co-Liquefaction of Forest Biomass and Waste Plastics	$727,677.00
Auburn University – Novel Biotechnology that Converts Agricultural and Municipal Waste into Bioplastics	$294,008.00
HudsonAlpha Institute for Biotechnology – Next Generation Crops for a Diverse Alabama Agricultural Economy	$968,365.00
The University of Alabama in Huntsville – Versatile Training to Provide an Agile, Advanced Manufacturing Workforce in Alabama	$603,206.00
Auburn University – Polymer Smart Machines	$268,353.00
University of North Alabama – Surface Plasmon Resonance-based Biosensors	$10,353.33
Auburn University – Novel and Sustainable Feed Binder from Soybean Hulls	$300,432.00
The University of Alabama at Birmingham– Amputation	$700,000.00
The University of Alabama at Birmingham – Pneumococcal Vaccine	$635,926.67

The University of Alabama – Innovative Wood-Concrete Composite Structural Elements for Resilient Modular Building and Transportation Structures

This research project focuses on the development of innovative materials and construction techniques that can help improve the sustainability and resilience of Alabama building and transportation infrastructure. The overall research goal of this project is to develop innovative hybrid structural building elements using fiber reinforced concrete and laminated wood materials (traditional lumber and/or bamboo); and characterize their performance under several loading

conditions. As part of this research, we will develop two types of hybrid elements and perform large-scale testing of these elements whereby they will be subjected to mechanical and impact loading (representing expected debris impact during a tornado event). We will also investigate the acoustic and thermal performance of these elements to understand their energy efficiency for building applications. The novel and validated structural elements can provide opportunities to attract new industries and supply chains related to prefabricated building systems.

We continued the literature review on the CLT-concrete composite construction during this quarter. Few gaps in the literature related to interface preparation and moisture transfer potential of the UHPC-to-CLT interfaces were identified. Additionally, we performed analysis of experimental data from UHPC- CLT panel tests and developed a test specimen matrix to prepare the test specimens for next quarter's work. We have also developed analytical models for predicting the structural response of the composite CLT-concrete construction. The process to recruit a second PhD student to work on this project has been completed as well.

Auburn University – Advanced Liquid Transportation Fuels from Co-Liquefaction of Forest Biomass and Waste Plastics

The main goal of this project is to advance economic development in Alabama (and the nation) through reinvigoration of our natural resource-based industries and to establish new industries based on advanced liquid fuels from woody biomass grown in the state and the waste plastics collected from our local cities. Woody biomass prevalent in Alabama will be co-liquefied with waste plastics using a pyrolysis technology, which will then be subjected to hydrogen treatment to produce jet- and diesel- fuels. The funding from the Alabama Innovation Fund will be used to overcome technical barriers faced in converting woody biomass to biofuels and waste plastics recycling. The research will be focused on developing: (i) a process that would require lower capital and operating cost for biomass liquefaction; (ii) catalysts for the production of jet- and diesel-fuels; and (iii) a pathway for recycling waste plastics for the production of liquid fuels along with woody biomass. The team will leverage existing infrastructure and expertise at the Center for Bioenergy and Bioproducts at Auburn University.

The project aims to produce transportation fuels using biomass and non-recyclable waste plastics. During this quarter, we processed woody biomass such as pine, hybrid poplar, Douglas fir, and eucalyptus to produce liquid (bio-oil) using the pyrolysis process. The bio-oil yield from these biomass types is about 40% by mass, whereas biochar yield is about 20% by mass. Bio-oil is an intermediate feedstock for producing green carbon transportation fuels, whereas biochar can be used to improve soil health and sequester carbon. The Recipient also performed a two-stage hydrotreatment process using noble and transition metal catalysts. The mild-hydrogen treatment at 150℃ was conducted in which carbonyl and carboxyl functional groups were transformed into alcohols, and the bio-oil was stabilized. After the first stage, the upgraded oil's higher heating value (HHV) increased to 23 MJ/kg from 17 MJ/kg, and the total acid number (TAN) decreased to 58.8 mgKOH/g from 70.1 mgKOH/g, respectively. After the second stage hydrotreatment over CoMo/alumina at 400℃ for 5h, the pyrolysis oil had an 89% decrease in the acid number (7.7 mgKOH/g) and 130% increase in energy content (39.12 MJ/kg) compared to the feedstock (70.1 mg/KOH and 38.72 MJ/kg). We successfully stabilized the pyrolysis oil in the first stage and hydrotreated it further in the second stage.

In the next quarter, the Recipient will characterize bio-oils produced using different biomass types. These oils will be measured for elemental analysis (CHNS), heating value, total acid number (TAN), and functional groups. Further, we will continue bio-oil upgrading work.

Auburn University – Novel Biotechnology that Converts Agricultural and Municipal Waste into Bioplastics

Alabama is one of the top agricultural producing states in the U.S., with annual agricultural exports exceeding $1 billion. As a result, there is a significant amount of organic wastes produced in the state, and Alabama ranks 14th among all states in terms of biogas generation potential from organic waste through anaerobic digestion (AD). These organic wastes represent an underutilized renewable feedstock for biofuel and biochemical production. This project aims at researching and assessing the economic feasibility of converting organic wastes into bioplastics. Specifically, the project will develop and optimize a prototype of a patent-pending biotechnology that enables the conversion of organic wastes into bioplastics, and to assess its technical and economic feasibility at scale through techno-economic analysis (TEA). In the proposed technology, a microalgae-methanotroph coculture will be cultivated in a novel patent-pending circulation coculture biofilm photobioreactor (CCBP) to convert biogas (both methane and carbon dioxide) derived from organic wastes into microbial biomass while simultaneously recovering chemicals from AD effluent to produce treated clean water. The produced mixed microbial biomass can be economically processed to produce high-value bioplastics that are in rising demand. The project will advance the progress of the patent pending biotechnology towards commercialization, which has potential to create many new jobs in the State of Alabama.

During Q2 2022, the patent for the circulation coculture biofilm photobioreactor (CCBP) was officially granted by the United States Patent and Trademark Office (USPTO). The project team is constructing a bench-scale CCBP on AU campus. A commercial portable anaerobic digester (AD) was set up at Auburn University Fisheries Center for processing food waste and fish sludge to generate biogas.

HudsonAlpha Institute for Biotechnology – Next Generation Crops for a Diverse Alabama Agricultural Economy

The HudsonAlpha ADECA/ARDEF project, in collaboration with Auburn University Crop, Soil and Environmental Science and Pathology Departments, and Alabama A&M Winfred Thomas Agricultural Research Station will develop a pilot pipeline to import and test new crop varieties that could be deployed by Alabama farmers. We will connect the advanced agronomy crop research at Alabama Land Grant Institutions to the advanced plant genetic and genomic science expertise at HudsonAlpha. For two crops, barley and beans, the team will bring in diverse germplasm, plant and evaluate cultivars to advance in additional trials. Barley will be tested as an overwinter crop for a spring harvest in Northern and Southern Alabama and dry beans will be tested as a summer crop in North Alabama. The team will evaluate disease, environmental, and weed pressure and other important agronomic traits for a crop to be successful in our challenging farming climate. As part of the goals, the partners will focus on increasing economic awareness of local barley and beans, connecting into existing educational and career development frameworks, and partnering with end users for brewing and food applications to increase the value of these Alabama crops. As this project develops, the teams will work with local farmers who are interested in planting alternative crops and engage stakeholders in workshops to discuss the science of next

generation crop development to expand partnerships and apply this strategy to more crops useful for Alabama. With this newly developed research and collaborative infrastructure to bring in additional crop options, we can take control of the future of Alabama farming by optimizing the genetics and germplasm for Alabama, train new scientists in advanced plant science, open up new economic development in agriscience, and expand the current impact of local food and beverage industries.

In Q2 2022, the field station teams harvested the overwinter barley trials at two Auburn Field stations (Tennessee Valley and EV Smith) and at Alabama A&M (Winfred Thomas). Initial results are promising for several varieties in Northern Alabama, with most of these being Virginia Tech varieties that have been selected for cold tolerance. Due to the extreme winter temperatures in Alabama, most spring barley varieties had heavy yield losses. We are currently phenotyping these varieties for malting and brewing quality characteristics. This quarter we added a project manager who will help coordinate field station work and is responsible for outreach to potential farmers and breweries who would be using locally grown barley. We also added a PhD student at Auburn who will lead the economic modeling aspect of this project, developing a large-scale consumer survey that will guide our future economic decisions on pricing and feasibility. We have begun to collaborate on malting local barley with the Old South Malt House in Cullman, a newly expanded malt house that will process grain produced in this project for test batches at local breweries. Along with malting, we have also done outreach to local breweries to expand the potential impact of this project.

The University of Alabama in Huntsville – Versatile Training to Provide an Agile, Advanced Manufacturing Workforce in Alabama

The overall goal of the proposed institutional collaboration is to assist in the transition of Alabama from a low-labor-cost manufacturing state to a leader in the research and development of next generation manufacturing sciences. To meet this goal, our primary objective is to expedite trans-disciplinarily, inter-disciplinarily, and multi-disciplinarily training of Alabama for entering the industrial and government workforces and contributing to the implementation and advancement of the emerging manufacturing technology through Additive Manufacturing.

Resources from this grant will expand our Additive Manufacturing Laboratories thereby enhancing and expanding our education and research capabilities. This collaborative environment will provide our students with the skills necessary to support research and development activities within industry and government. Quotations have been obtained for equipment necessary to expand our Additive Manufacturing Laboratories thereby enhancing and expanding our education and research capabilities. Student teams from UAH and Calhoun Community College (CCC) have been formed to address projects that will assist companies in qualifying and certifying additive manufactured components.

Auburn University – Polymer Smart Machines

This project aims to research and develop the foundational building blocks of polymechatronics, which will enable the realization of 3D printable polymer smart machines. The research and development includes designing, fabricating, modeling, and characterizing piezopolymer versions of traditional mechanical and electrical building blocks such as actuators, sensors, energy harvesters, energy storers, and analog & digital circuit elements. Conventional 3D printed

structures do not actuate or compute. However, if successful, the proposed project will lead to the first 3D printable smart machines that can actuate and compute without the need of externally-manufactured actuators and circuits. Compared to traditional devices, polymer smart machines are expected to be less expensive, easier to manufacture, biocompatible, recyclable, use less energy, operate over a larger range of temperatures, offer new functionalities, and be more environmentally friendly. Such attributes are expected to enable a wide spectrum of novel mechatronic components and products for consumers.

During the second quarter of this project, after equipment training at the IEN (Institute for Electronics and Nanotechnology), we started fabricating our very first microscale structures on the Nanoscribe. This process includes designing the structures in COMSOL, exporting the designs in STL file format, importing the file into the DeScribe software used by Nanoscribe, adjusting the fabrication process parameters, and developing the structure. Both design and fabrication are skills we are currently developing through our experiences of continuous use, assessment, and corrective actions. Quantitively, devices are fabricated at least three times per week, based on equipment availability. Our project sees the most use of the Nanoscribe. Numerous fabrication parameters affect the speed and quality of fabrication. We are currently determining the parameters' ranges and noting the effect of modified values on the resulting structures. Various materials have been ordered from China that will allow us to mix piezo and conductive materials into the polymerizable resin. Nearly all of the materials have arrived. However, due to the supply-chain problem, some materials take a little longer to arrive. Once the materials have arrived, we can start fabricating piezoelectric and conductive materials. During our testing, we demonstrated that the Nanoscribe could polymerize through previously polymerized geometries. Such ability is important for polymerizing conductive geometries onto piezoelectric geometries for fully functioning actuators. Our tests consisted of fabricating large, closed cuboid structures, then fabricating a medium-sized cuboid inside the larger cuboid, and finally fabricating a small sphere inside the medium cuboid. Such transparency is also beneficial to a company interested in licensing this technology for microscale camera optics applications in smartphones, tablets, etc. Regarding issues impacting progress, we are currently learning how to create robust enough structures to survive the development process. We've discovered improvements which include 3D printing a substrate, lengthening the stitching overlap between printed sections, and lengthening the laser polymerization time. The quality of the fabricated structures is quite sensitive to various parameters.

University of North Alabama – Surface Plasmon Resonance-based Biosensors

Biosensors are devices that convert a biological response into an electrical signal; and, they are increasingly prevalent across multiple industries including (i) food industry to check and verify the quality of the vegetables, fruits and meat, (ii) medicine and health industry to diagnose biological samples for diseases, ailments etc., and (iii) monitor safety industry to identify harmful chemicals. The current state of biosensors' sensitivity is often limited to minute concentrations of the molecules/agents under testing, usually in the range of 5 ng/mL. Due to this limitation, the biosensor output may lead to a failed detection and/or recognition that might cause harm to life.

A novel technique will be used to enhance the sensitivity of the biosensors based on the principle of surface plasmon resonance (SPR). Numerical investigations have suggested that this novel technique can improve the sensitivity by at least 5-fold, which facilitates easier detection of biomolecules in concentrations not possible using other biosensors. Upon building and successful

testing of the SPR sensor system with regular glucose samples, the plan is to detect cow milk allergy agent and Staphylococcal enterotoxin B (SEB), which are important biomolecule agents in the food industry. The proposed biosensor setup can also be used for medical diagnostics.

During this quarter, a fixture to hold the optical prism and the glass slide in position on the concentric rotational motor stage was CNC fabricated in the department lab. A significant amount of noise in the SPR curve was noticed, currently tests are being performed to identify the source of this noise and obtain a clean noiseless SPR curve.

Auburn University – Novel and Sustainable Feed Binder from Soybean Hulls

The goal of this project is to establish a low cost, high value, and novel compound feed binder from soybean hulls (SBH), a co-product of soybean processing for oil and meal production. The specific objectives of this project are twofold: 1) to scale-up feed binder production to around 1.5 kg/hour and optimize process conditions for production; and 2) to scale-up shrimp feeding trials simulating shrimp farming operations at a commercial shrimp operation in West Alabama. Successful completion of this project will establish a high value and novel compound feed binder platform using 100% soy hulls that is ready for commercial scale productions and applications with significant economic and environmental benefits: it will significantly enhance competitive advantage of shrimp farmers in Alabama by reducing their feed costs. This will in turn improve employment opportunities in seafood farming and processing sector, making more local seafood and services available to the citizens of Alabama. In addition, it will also significantly improve water quality by reducing leached nutrients.

During this quarter, we have produced 3 feed binder samples (a total of 2 bone-dry kilograms) using our new equipment purchased and installed as described in the last quarterly report (January – March 2022). Some issues have arisen with steam leakage, and it takes too long to cool down with the new equipment. We are working on addressing these issues so that we can start the scale-up production, characterization, and optimization of the feed binder using the two pieces of equipment.

University of Alabama at Birmingham – Amputation

Approximately 1.6 million people live with an amputation within the U.S., and amputation cases are expected to rise to approximately 3.6 million by 2050. 185,000 people have an amputation each year in the U.S., with a significant increase noted associated with COVID-19 infection. The conventional technology is unable to adapt to the dynamic residual limb as it atrophies over time and swells with heat or weight gain. Percutaneous osseointegrated prostheses (POP) are a promising development for the limb-prosthesis interface involving the direct skeletal attachment of the prosthetic device. Alongside the promising benefits of POP, significant risks are present at the bone-implant interface including superficial and deep infection, inflammation, insufficient osseointegration, lack of vascularization, and implant loosening. The main goal of this project is to develop the multifunctional nanomatrix coating on POP that can be clinically translated for improved osseointegration of prosthetics, and other types of orthopedic and dental implants in order to help promote healing and prevent infection.

The project has successfully started, recruited research staffs, and made progress to synthesize the multifunctional nanomatrix coating. During last period, this project has made a good progress

including IACUC approval, External Advisory Committee meeting, and successful fabrication of antibiotics loading liposomes.

University of Alabama at Birmingham – Pneumococcal Vaccine

Streptococcus pneumoniae is a leading cause of bacterial pneumonia and meningitis, resulting in more than 2 million pneumococcal infections and more than 6,000 deaths each year in the United States. Mortality rates are high especially in very young, elderly, and immunocompromised individuals. In Alabama, invasive *Streptococcus pneumoniae* represents a special concern to the State's aging population, as well as in the rural and economically deprived communities with limited access to routine health care. The currently available pneumococcal vaccines in clinic, *e.g.*, PPV23 and PCV13, have limitations. For example, PPV23 is not effective in children younger than two years old, the elderly, and immunocompromised individuals; and while PCV13 is effective for children, it has limited serotype coverage (fewer than PPV23) and requires an inconvenient four-dose immunization schedule for infants and young children. Moreover, none of these clinical vaccines provide effective protection against *S. pneumoniae* serotype 3 (ST3), a significant cause of morbidity and mortality worldwide. In this project, we will develop enhanced PPV23 and PCV13 vaccines which can provide increased protection with reduced number of immunizations. The enhancement will be achieved by employing the potent new vaccine adjuvants recently discovered in the Principal Investigator's laboratory at UAB. Success of this project will benefit the citizens of Alabama and have broader positive impacts on global health as well.

In Q2, we conducted the planned *in vivo* immunological studies in mice. Based on the results, we identified the most effective new adjuvant that significantly boosted immune responses induced by a clinical pneumococcal vaccine. The new adjuvant is one of the saponin series adjuvants developed by the PI at UAB. With the addition of this new adjuvant to the clinical pneumococcal vaccine, the new vaccine formulation significantly enhanced the antibody responses against all the selected representative *S. pneumoniae* serotypes, including the most notorious and challenging serotype.